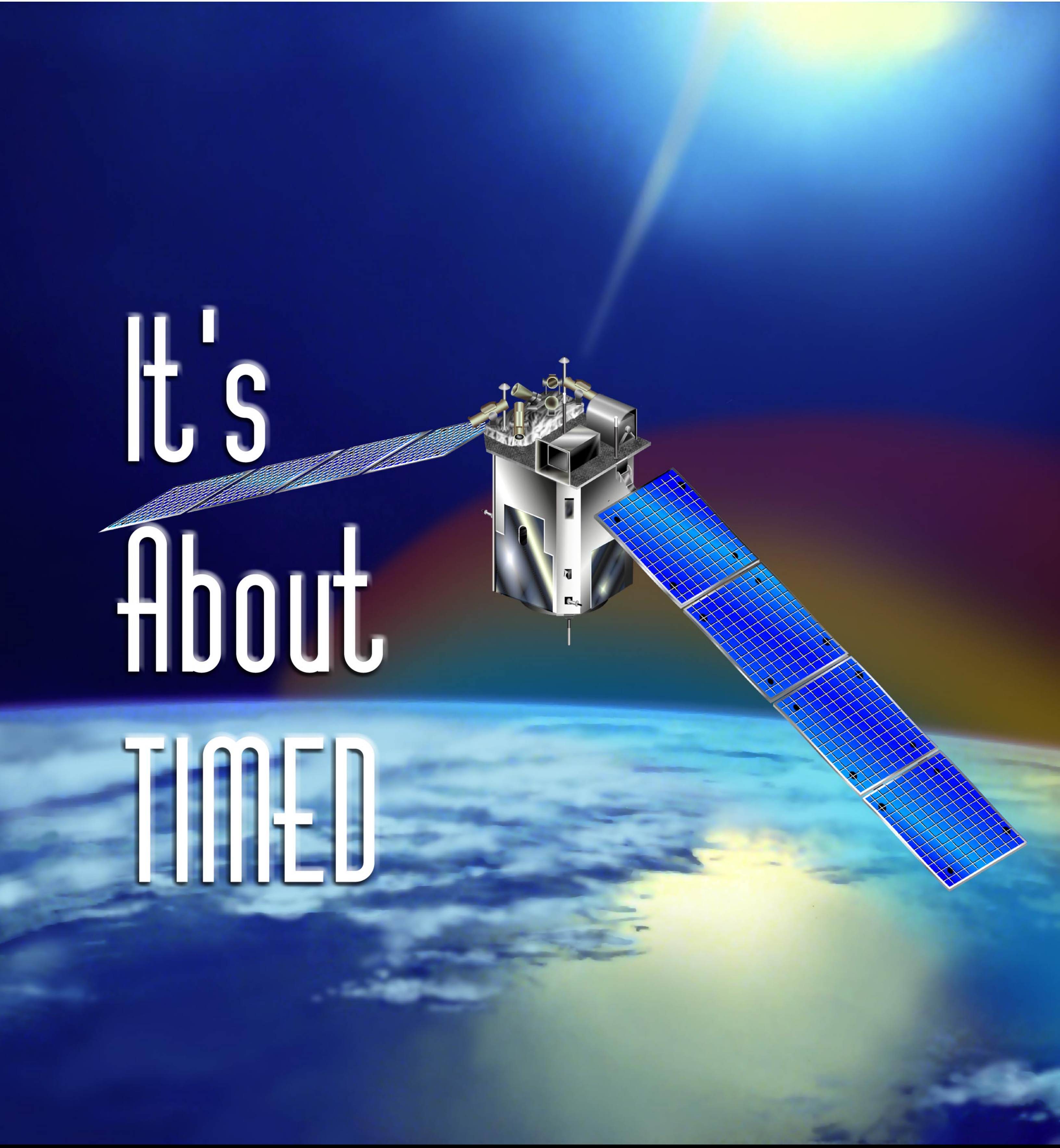
It's About TIMED



Educational activities developed by a teacher from the University of Maryland Graduate Fellows Program (UMGFP) while at The Johns Hopkins University Applied Physics Laboratory.

Dedication

To Nancy and Bruce Daniel, my parents, who have always encouraged me, and still do, to aim for the stars! Thanks for everything!!

To my three "adopted" nieces Shelby, Shauna, and Shaylin Kennedy for reminding me why I went into teaching when I seem to forget. I Love You!

To my past, present, and future students whom I love and encourage with my classroom motto: "Aim for the stars, through teamwork we achieve!"

Contents

Acknowledgements

I would like to send out many thanks to the following individuals without whose help I would not have a better understanding of the world around me and for helping to answer the age-old question from my students: "When will I ever use this in real-life?"

- Judith Anderson—Teacher Advisor
- Mary Anderson—Graphic Artist
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- Steve Gemeny—Lead Ground Control Station Engineer for TIMED
- Kevin Heffernan—Instruments System Engineer
- Christine Hilliard—Secretary
- Mary Ann Johnson—Secretary
- Beth Snyder Jones—Director of the University of Maryland Graduate Fellows Program.
- Stacy Mitchell—Best photographer and tour guide APL has
- Frank Morgan—Post-Doctoral student working on TIMED
- Dr. Larry Paxton—GUVI Project Scientist
- Dr. Jeng-Hwa Yee—TIMED Project Scientist
- Jessica Thomas—MCTP intern
- The graphic arts department
- Photography department

Thank you for your time and effort for helping me.

Introduction

This internship was sponsored by The Johns Hopkins University Applied Physics Laboratory (JHU / APL) for the University of Maryland Graduate Fellows Program (UMGFP). The UMGFP provides an opportunity for middle and high school teachers to experience science and mathematics in a “real-world” setting by participating in ongoing research at a variety of research facilities throughout Maryland.

My wish is that through these lessons, teachers and students will gain a better understanding of the TIMED satellite as well as explore how mathematics is the basis for all sciences. I also wanted to answer the question I am asked every year: “When am I ever going to use this in real-life?” My answer now will be: “Here are some real-life examples.” If you have any further questions on the components of the lessons, please feel free to contact me.

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UNIT I: GENERAL MATHEMATICS

Lesson 1: SABER Scale – The Picture

Links to Outcomes:

- **Problem Solving**—Demonstrate the ability to use mathematics in a cooperative learning and hands-on environment.
- **Communication**—Communicate mathematical concepts verbally and in written form.
- **Reasoning**—Make conjectures and reason mathematically.
- **Connections**—Demonstrate the ability to connect mathematics with real-life applications.
- **Measurement**—Demonstrate the ability to apply concepts of measurement using scale drawings.
- **Relationships**—Demonstrate the ability to apply concepts of coordinate graphing.

Overview: The lesson will use the coordinate graph system, scale modeling, and proportions. A drawing of the SABER instrument (Sounding of the Atmosphere Using Broadband Emission Radiometry) from the TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics) satellite will be used to show how scale models are created and used.

Grade/Level: Grades 6–8: Middle School General Mathematics
Grades 9–10: High School General Mathematics

Duration/Length: 1-2 lesson periods depending on students' ability (*The best time is right before a holiday.)*

Prerequisite Knowledge:
- Ratio and proportion
- Scale drawing
- Coordinate graphing

Objectives:
- Locate an object on a coordinate grid.
- Enlarge a picture of SABER by using coordinates.

Materials/Resources/Printed Materials:
- Crayons, colored pens, or markers, rulers
- Each student needs a piece of the mystery puzzle
- Each student needs a piece of white paper either 2 in. by 2 in. or 3 in. by 3 in. depending on how big you want the picture to be.
- Background information on TIMED and SABER provided in the lesson.

Development/Procedures: Discuss the relationship between math and science, and how scientific information can be explained through mathematics. Discuss the mission of TIMED and the instrument SABER's role in the overall mission.

<u>This is a mystery picture, please don't show them what the picture is supposed to be ahead of time</u>. Cut the picture provided along the grid lines. Each student should receive a piece of the puzzle and the square to enlarge the picture. I recommend the 3 in. by 3 in. squares, but it can be done with the smaller squares.

Allow the students time to draw and color their piece. They may ask what colors they should use. Let them choose whatever colors they want. Since the SABER instrument and the TIMED satellite are not that colorful, the use of color will help brighten the picture. This is a good activity to do before a holiday or long break because it allows students to be active and to chat while learning.

When the students have finished, encourage them to make sure they label the back with the coordinate just in case the pieces are mixed up. Place the pieces on the chalkboard or a larger sheet of paper in the order the pieces should appear on the grid. Students should be able to step back and see their creation. If done right, it should look like the smaller version. Display the picture where all students can see it.

Evaluation: This activity is very difficult to evaluate. You could invite your school's art teacher to discuss some ways they may improve the picture the next time. I would also have some work on proportions and scales that students could do on their own.

Extension/Follow-Up: The students could 1) complete the other picture provided, 2) construct three-dimensional displays in the form of life-size models or dioramas, or 3) work with the science teacher on enlarging a cell or other organism the students might be studying.

Background Information on the TIMED Satellite and the SABER Instrument

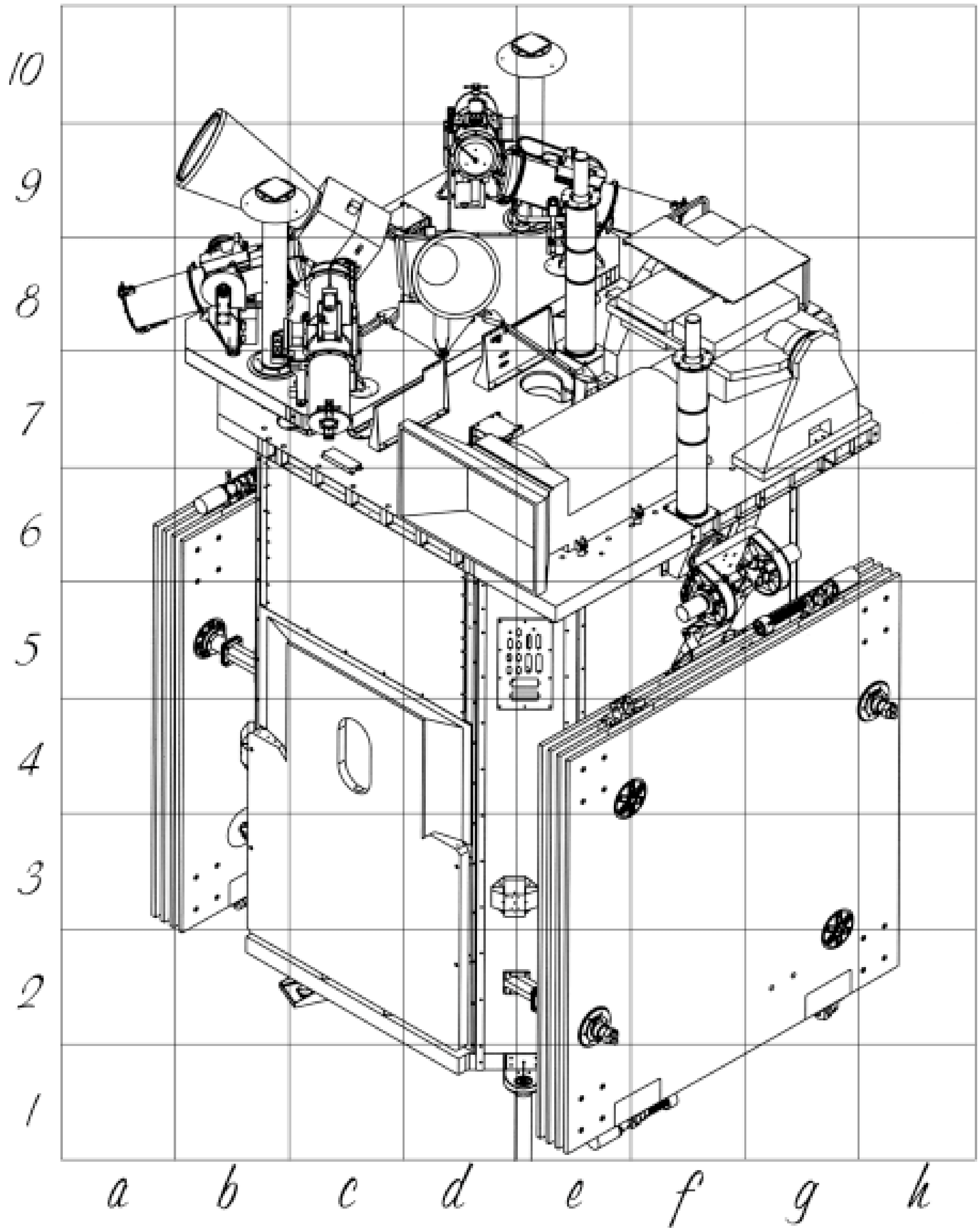
TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is the one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send up a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. Teachers and students should study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes such as global warming.

SABER is one of the four instruments supporting the TIMED mission. SABER stands for Sounding of the Atmosphere Using Broadband Emission Radiometry. SABER's mission is to explore the mesosphere and thermosphere to increase our knowledge of the chemical reactions taking place from solar radiation. SABER will not directly measure the temperature and pressure of the mesosphere and thermosphere, but will infer these by parameters from measurements of other elements. SABER will also examine the dynamic structure and amount of each chemical in the reaction process. SABER will look for these chemical reactions by using remote sensing in the infrared region of the spectrum.

For more information on the TIMED Mission and the SABER instrument, please view the home page at http://sd-www.jhuapl.edu/TIMED .

1 Square = 1"

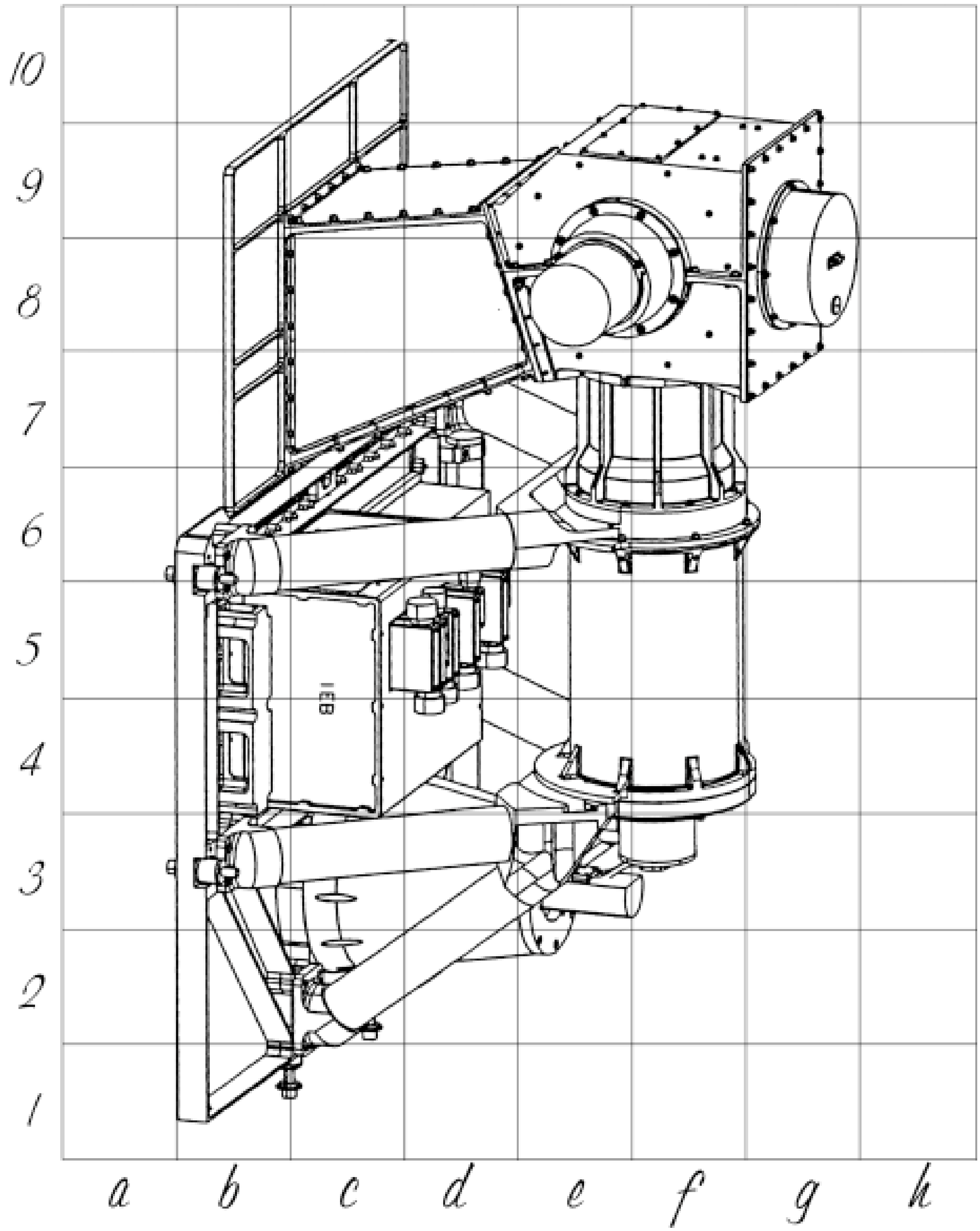
TIMED



How many times larger in area is your drawing than the original drawing?

1 Square = 1"

SABER



How many times larger in area is your drawing than the original drawing?

Lesson 2: SEE Surface Area and Light

Links to Outcomes:

- **Problem Solving—**Demonstrate the ability to solve problems from within and outside of mathematics with applications to real-life situations.
- **Communication—**Demonstrate the ability to communicate mathematics with its unique language and symbolism.
- **Reasoning—**Demonstrate the ability to reason logically, and to make and test conjectures.
- **Connections—**Demonstrate the ability to make connections among several mathematical properties with respect to the mathematical discipline and other disciplines.
- **Cooperation—**Demonstrate the ability to solve problems in a cooperative setting.
- **Technology—**Demonstrate the ability to use a computer-based laboratory (CBL) with temperature monitor.
- **Algebra and Geometry—**Demonstrate the ability to apply algebraic and geometric concepts in the process of solving problems in classroom settings as well as in real-life situations.

Overview: This lesson involves classroom and real-world problem applications of algebraic and geometric properties associated with the surface area of a sphere and proportions. The lesson is focused on the SEE (Solar Extreme Ultraviolet Experiment) instrument for the TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics) satellite.

Grade/Level: Grade 8: General Mathematics (Surface Area and Volume Unit)
Grades 9–12: General Mathematics (Algebra and Geometry applications)

Duration/Length: 1–2 days depending upon the ability and comprehension level of the students.

Prerequisite Knowledge:

- Terminology of ratios and formulas
- Measuring with a ruler
- Ability to follow detailed instructions
- Basic use of a CBL

Objectives:

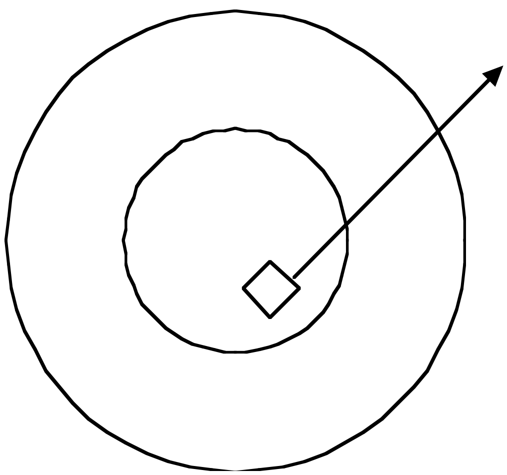
- Do a simple experiment to simulate SEE.
- Use a CBL to gather data.
- Calculate the imaginary surface area of a one-dimensional image.
- Calculate the growth proportion of the image.
- Calculate the energy.

Materials/Resources/Printed Materials:

- Background Information provided on TIMED and SEE
- Flashlight for each group
- Rulers
- CBL with light monitor
- Student worksheet – Overhead of this as needed.
- Calculator as needed.

Development/Procedures: Discuss the background information on TIMED mission and SEE instrument.
Students should be grouped in threes and each group should receive three student worksheets, flashlight, CBL with light monitor, and a ruler. The directions for the experiment are on the worksheet.

The experiment entails one student with the flashlight standing 1 yard (meter) away from a wall to shine the light on the wall and a second student to measure the diameter of the circle produced by the flashlight. The third student needs to record the data. This action is repeated two more times. Each time the student with the flashlight moves back 1 yard. The experiment should be repeated with the flashlight and CBL gathering light from a spot 1 foot away from the wall where the flashlight hits that spot each time the student moves back.



The spot may be in a different location for each group, but it must be constant. Once it is picked, the student with the flashlight is the only person who should move. The recording student gathers the data during each move.

Students will struggle with the light monitor trying to get it in the right spot. I contacted Texas Instruments about whether it would be better to have the light monitor against the wall. The technician said the reason you need to stand away from the wall is so you do not pick up the reflected light. The reason I have students start with finding a place on the wall is so they have a constant point on which to point the light monitor. If you find another way, please contact me or JHU/APL.

After the students have finished the experiment, they need to complete the student worksheet. Students may find it easier to leave Π as the symbol rather than get a decimal answer.

Evaluation: Circulate throughout the room during the different steps of the activity to determine students' understanding. Further evaluation will occur as part of more typical evaluation procedures.

Extension/Follow Up: Work with the science teacher on the subject of the Sun's energy that heats the planets, as well as how the planets receive and give off energy.

Background Information on TIMED and the SEE Instrument

TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is the one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send up a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. Teachers and students should study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes such as global warming.

The SEE instrument is one of four instruments on the TIMED satellite. SEE stands for Solar EUV Experiment. SEE will study the solar extreme ultraviolet (EUV) radiation, which is one of the major energy sources for the upper atmosphere. This energy output varies throughout the Sun's solar cycle. This energy in the Earth's upper atmosphere drives the reaction which creates different chemical reactions that would not have existed had it not been for the EUV radiation. The experiment in this lesson is to represent how energy is dispersed over the planet at any given time.

For more information on the TIMED Mission and the SEE instrument, please view the home page at http://sd-www.jhuapl.edu/TIMED.

Student Worksheet for SEE Surface Area and Light

Name ______________________________

Date ______________________________

Name of person in charge of the flashlight

____.

Name of person doing the measurements and working the CBL______________________________.

Name of person recording the data

____.

Step 1. Gathering Diameters of Circles

The measurement of the diameter of light needs to be the brightest circle not including the lighter rays of light.

1) The diameter of the circle 1 of light 1 yard or 1 meter from the wall.

   ____

2) The diameter of the circle 2 of light 2 yards or 2 meters from the wall.

   ____

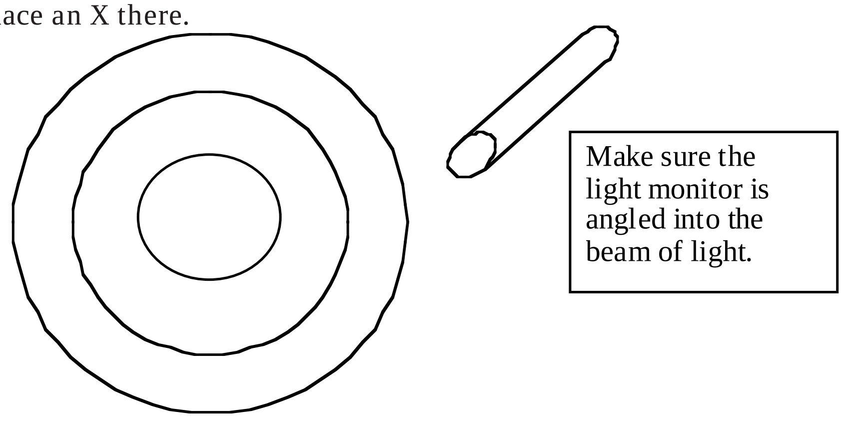
3) The diameter of the circle 3 of light 3 yards or 3 meters from the wall.

   ____

Step 2. Measuring Temperature of a Spot

In step 1 you were creating concentric circles. The person who holds the light monitor needs to choose one spot on the wall that regardless of how large the circle of light becomes, the position of the monitor does not change. Then the person needs to move the light monitor 1 foot from the wall. Hold the light monitor at an angle into the beam of light from the flashlight.

In the smallest circle provided, estimate where the temperature monitor was placed into the beam of light. Place an X there.



4) The light after 2 minutes, 1 yard or 1 meter away from the wall.

____

5) The light after 2 more minutes, 2 yards or 2 meters away from the wall.

____

6) The light after 2 more minutes, 3 yards or 3 meters away from the wall.

____

Step 3. Calculate surface area of an imaginary sphere using the diameter of the circles of light from step 1. Surface Area Formula: $S = 4 \Pi r^2$

Leave answers in pi form.

7) radius from circle 1 = ________ Surface Area from circle 1 = ________

8) radius from circle 2 = ________ Surface Area from circle 2 = ________

9) radius from circle 3 = ________ Surface Area from circle 3 = ________

Step 4. Calculate the ratios of the surface areas (from step 3) of the circles. Simplify!

10) circle 1 to circle 2 = ______________________________

11) circle 2 to circle 3 = ______________________________

12) circle 1 to circle 3 = ______________________________

Step 5. Calculate the ratios of the light (from step 2) of the circles. Simplify!

13) circle 1 to circle 2 = ______________________________

14) circle 2 to circle 3 = ______________________________

15) circle 1 to circle 3 = ______________________________

Step 6. Answer the following questions from the information gathered.

16) If the flashlight represents the Sun's energy and the circle of lights represents different planets, what can you conclude about the planets' position to get energy?

17) If we had two different size spheres side-by-side illuminated from the same energy source, would the point on the larger sphere receive the same amount of energy as a point on the smaller sphere?

For questions 18–22, use the ratios calculated in questions 10 to 15. Let circle 1 represent Earth, circle 2 – Saturn, and circle 3 – Jupiter.

18) If a tree is 12 feet tall on Earth, how tall would the same tree have to be on Jupiter in order for it to be the same proportion to the one on Earth?

19) If a light monitor on Jupiter picked up a light beam from the Sun with the measure being 23 V, how much brighter would the beam from the Sun be on Saturn?

20) If an ocean on Saturn is 23,000 miles across, how much smaller would it be on Earth to keep it in the same proportion?

21) If a light bulb puts out 100 W on Earth, how much would the wattage be on Jupiter in order for it to be the same proportion to the one on Earth?

22) If a satellite were built to scale with the planet Saturn and it was 200 feet tall, how much taller would that same satellite have to be on Jupiter for it to have the same proportion?

UNIT II: ALGEBRA

Lesson 1: Trends in TIMED

A Mathematics Lesson to collaborate with *It's about TIMED! Moving Chemistry into the Year 2000. Student Inquiries into Atmospheric Chemistry*
By Ann Lillian Coren

Links to Outcomes:

- **Problem Solving—**Demonstrate the ability to solve problems from within and outside of mathematics with applications to real-life situations.
- **Communication—**Engage in group discussions to interpret the data given and line-of-best fit.
- **Reasoning—**Demonstrate the ability to reason mathematically. They will make conjectures with regards to given information and graphs.
- **Connections—**Demonstrate connecting algebra with real-world applications.
- **Technology—**Demonstrate using the graphing calculator to determine line-of-best fit.
- **Patterns and Relationships—**Demonstrate by using a graphing calculator the ability to recognize patterns and to draw conclusions about line-of-best fit.
- **Algebra—**Demonstrate algebraic concepts involving equations and graphs.

Overview: This lesson will demonstrate the connections between graphing scatter plots and line-of-best fit. You will be able to discuss with your students positive, negative, and no correlation of the scatter plots as well as the difference between the trend line and line-of-best fit.

Grade/Level: Grades 8-12 : Algebra 1 or Algebra 2 review

Duration/Length: 1 – 2 lesson periods depending on students' ability

Prerequisite Knowledge:
- The coordinate system of graphing
- Terminology
- Plotting points
- Properties of linear equations
- Knowledge of basic functions and relations
- Use of a graphing calculator (**TI-81, TI-82, or TI-83**)

Objectives:
- Label and graph coordinate plane system.
- Interpret and make predictions of scatter plot graphs.
- Discuss the difference between a positive, negative, and no correlation of scatter plot points.
- Discuss the difference between a trend line and line-of-best fit.
- Use the graphing calculator to calculate and draw line-of-best fit.

Materials/Resources/Printed Materials:
- Graphing calculator
- Ruler

- Student Worksheet
- Overhead of Student Worksheet
- Overhead of Scatter Plot Points for Noctilucent Cloud Sightings
- Colored pencils or pens
- Background information on TIMED and Noctilucent Clouds

Development/Procedures: Discuss the relationship between math and science and how scientific information can be explained through mathematics. Discuss the mission of TIMED and how noctilucent clouds were our first indication of some different elements in our atmosphere. Students need to have a basic understanding of a graphing calculator before doing this activity. Included are step-by-step procedures for making a TI -82 large enough to make an overhead. If you or your students use an 81 or 83, the steps might vary slightly.

Walk students through the procedures for finding line-of-best fit on the calculator. Ask students to compare their scatter plot graph to the one the calculator gives. Have students look at the window range and discuss the maximum and minimum values of the *x* and *y* axes.

Have students graph the scatter plot points by hand on their student worksheet. This includes labeling the axes and graphing the ordered pairs. (Note: I try to remind my students that the ordered pairs are in alphabetical ordered pairs so they need to go right or left first before going up or down. I also use the image of an airport, i.e., the planes go down a runway before flying. If the coordinate is on the *x*-axis, the plane is waiting for take-off. If the coordinate is on the *y*-axis, it is a helicopter.)

Discuss and answer the questions (on student worksheet) about why they graphed only in quadrant 1.

Discuss with students the correlation of the points such as positive, negative, or none. Talk about trends with the points.

> <u>Trend lines are estimated lines of best fit</u>. They show the direction of the major flow of points. A good example is, if you were throwing jacks, the arm movement would be the trend line for the scattering of the jacks.

Have students draw in the trend line with a colored pencil or pen. Remind students that they should have the same number of points above and below their trend line. Since the trend line is an estimation or prediction of the flow, students' lines may vary slightly. Explain this to your students and try to correct the larger variations of the lines.

Have students estimate two points on their trend line. The two points might or might not be points that were scatter plot points. I try to use even number points on the line. Have students find the slope and the *y*-intercept for that line (on student worksheet). You will compare the results to the graphing calculator later.

After students have the line-of-best fit on their calculator, have them draw it on their graph with another colored pencil or pen. **Have students discuss and answer the questions on the Student Worksheet.**

Evaluation: Circulate to determine students' understanding. Further evaluation will occur as part of more typical evaluation procedures.

Extension/Follow-Up: Work with the science teacher to graph and interpret more real-life or simulated-type science experiments.

Background Information on TIMED and Noctilucent Clouds

TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is the one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. Teachers and students should study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes such as global warming.

Noctilucent clouds are found at altitudes of about 85 to 90 km, which is the mesosphere region. Most clouds are found in the troposphere and some in the stratosphere. Noctilucent clouds are found higher in the Earth's atmosphere later in the evening at high latitudes during summer months. Noctilucent clouds can be seen at that time because the setting sunlight is reflected off the bottom of them, giving the clouds the ability to be seen longer after the Sun has set. Scientists have taken some pictures of these clouds in the mesosphere that indicate they may contain ice. Thus, another reason for sending a satellite mission to this region is to find out what material produces the ice and how cold the atmosphere has to be for ice to form.

For more information on the TIMED Mission, please visit

http://sd-www.jhuapl.edu/TIMED.

Student Worksheet—Trends in TIMED

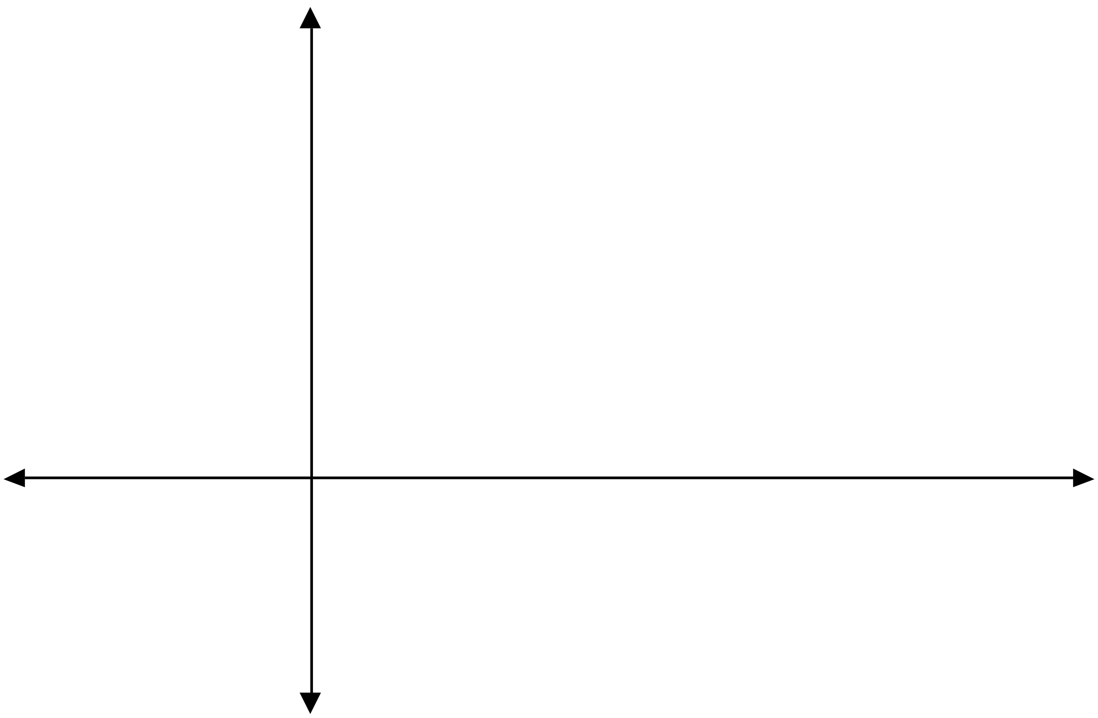
Name ______________________________

Date ______________________________

Show all work whenever possible.

1) Label the axes and graph the scatter plot points.

2) Why did the graph appear only in Quadrant 1?



3) What conclusion, if any, could you draw from this scatter plot?

4) What is the correlation between the points? Positive, Negative, or None

5) Draw in the trend line. Remember your trend line might vary from your neighbor's. The line should have the same number of points above and below it.

6) Estimate two ordered pairs that are on your trend line.

1 (__________, ____________)

2 (__________, ____________)

7) Using the two ordered pairs, find the slope of the line. m = ____________

8) Find the y-intercept. b = __________________

9) Using your slope and y-intercept, write the equation of the trend line.

____

10) Use the graphing calculator to graph and calculate the line-of-best fit. Draw in the line-of-best fit on your graph.

11) State the slope value from the calculator. m = __________________

State the y-intercept from the calculator. b = __________________

State the equation of the line from the calculator. ____________________

12) How do the two linear equations compare and contrast?

Noctilucent Cloud Sightings

Ordered pairs

x–value is the year the clouds were seen.
y–value is the number of clouds that were seen.

(1964, 21)	(1976, 31)
(1965, 19)	(1977, 43)
(1966, 22)	(1978, 45)
(1967, 28)	(1979, 38)
(1968, 30)	(1980, 35)
(1969, 24)	(1981, 51)
(1970, 19)	(1982, 48)
(1971, 23)	(1983, 44)
(1972, 25)	(1984, 42)
(1973, 26)	(1985, 46)
(1974, 40)	(1987, 38)
(1975, 35)	(1989, 49)

Steps for Line-of-Best Fit

Clear Lists

- Press {STAT}
- Press {4 or cursor down to 4 and press Enter}
- CLRLIST appears on the screen
- Press {2^{nd} #1 then comma above the seven and 2^{nd} #2}
- The screen should read CLRLIST L_1, L_2, then press Enter
- "Done" should appear on the screen, if not, redo the steps.

Edit Lists

- Press {STAT}
- Press {1 or cursor down to 1 and press Enter}
- L1 and L2 should appear on your screen.
- Enter data from the *x*-value into column L1 by typing the number and pressing Enter after each number to get to the next line.
- When finished with the *x*-values, use the cursor button to get to the top of L2 and to the process again using the *y*-values this time.
- Make sure all numbers are matched correctly, otherwise you will get a syntax error.

Graphing the Scatter Plots

- Press {2^{nd} then Y=}
- Press {1 or cursor down to 1 and type Enter}
- Press Enter when you have landed on the ON key. This darkens the key to turn on the scatter plot.
- The type of scatter plot should be the first little graph you see. This should be darkened. If not, land on it and press Enter to turn it on.
- X-Value should have L1 darkened. If not, land on it and press Enter
- Y-Value should have L2 darkened. If not, land on it and press Enter.
- Use the type of mark you can see the best.
- Press {ZOOM}
- Press {9 or cursor down to ZOOMSTAT}
- Scatter Plot should appear on the screen

Creating the Line-of-Best Fit

- Press {STAT}
- Cursor over to CALC
- Press {LINREG AX+B}
- LINREG should appear on the screen. Then press Enter, and $y = ax + b$ appears along with the values for a and b.

Get the Line-of-Best Fit into Y =

- Press {y = }
- If there are equations in any of the spots, either clear them or turn off the ability to graph them by landing on the = symbol and pressing Enter.
- Move the cursor to where you would like to have the equation.
- Press {VARS}
- Press {STATISTICS}
- Cursor over to EQ
- Press {REGEQ}
- The line should appear in the y = spot.
- Press {GRAPH}
- LINE-OF-BEST FIT should appear. If not, consult your TI – 82 manual.

Lesson 2: Solar Panel – Word Problems

Links to Outcomes:

- **Problem Solving—**Demonstrate the ability to solve problems from within and outside of mathematics with applications to real-life situations.
- **Communication—**Demonstrate the ability to communicate mathematics using its unique language and symbolism.
- **Connections—**Demonstrate the ability to connect algebra with real-world applications.
- **Technology—**Demonstrate the ability to use technology where appropriate.
- **Algebra—**Demonstrate the ability to perform algebraic concepts involved in solving word problems.

Overview: This lesson is not so much a student activity, but a teacher tool to help to show how algebraic concepts are used in a real-world application. The connection will be done through word problems related to the energy power from solar panels used on satellites.

Grade/Level: Grades 8–12; Regular and Honors Algebra

Duration/Length: 1–2 days as either warm-ups, lead-ins to the daily lessons, or follow-ups

Prerequisite Knowledge:

- Terminology
- Setting up word problems
- Solving equations

Objectives:

- Convert written words into mathematical equations.
- Solve an equation for the variable's answer.
- Respond in an appropriate manner

Materials/Resources/Printed Materials:

- Background information on TIMED and solar panels.
- Make overheads and / or worksheets from the lesson's printed material.
- The answer key is attached to this lesson.

Development/Procedures: *Warm-ups.*The questions are written so you may use them as a warm-up activity. You may want to use all the questions at one time or over a period of a few days.
Afterward, discuss the background information on TIMED and the importance of knowing the energy output from the solar panels that generate the power for the satellite.

Lead-in for daily lesson. Discuss the background information on TIMED and the solar panels provided in the packet.

When I have students working with word problems for the first time, I have them brainstorm words that represent the four operations. For example: Addition – total, add, plus, sum, altogether, etc.… My students are not fond of word problems, but when I show them all the key words they know that will help them solve the problems, they don't become as frustrated. I also explain that they have been solving word problems all their lives, but never knew it.

The first word problem is the formula used to help set up all the other problems given different parameters.

*Follow-ups.*These problems can be given at the end of a lesson as homework or as a review for a quiz or test.

Please discuss with your students the background information on TIMED and the importance of knowing the energy output from the solar panels generates the power for the satellite.

Extension Questions

1. Why do solar specialist play with the area of solar panels with 15% of efficiency?

2. Why do you think the area and position of solar panels matter to the satellite?

   Have students search the Internet to find answers. Answers will vary.

Evaluation: The teacher has many options:

- Circulate as the students are doing the activity
- Ask several students to come forward to explain their answers
- Collect the paper for a grade
- Give a more typical evaluation

Extension/Follow-Up: Work with the science teacher on an energy unit. Students could build a model of a satellite. They could calculate how much energy they were going to use and build mock-ups of the solar panels to match.

Background Information on TIMED and Solar Panels

TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send up a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. Teachers and students should study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes such as global warming.

Solar panels consist of solar cells, which are made from silicon or galliumarnite. These compounds convert photons to electrons to produce energy. Solar panels generate slightly more power than is needed for a satellite. The extra power is then stored in batteries for use when the satellite is in eclipse, i.e., when no power is being generated because the satellite is not in sunlight. During these periods, the satellite runs on battery power. A single solar cell has only about 15–20% efficiency. Because of this low rate, multiple cells are put on a panel so that it will work at approximately 98% efficiency. The kind of orbit a satellite will have determines the number of solar cells it will need, which determines the number of solar panels the satellite will need. Most satellites have an even number of solar panels for symmetry and balance.

For more information on the TIMED Mission, please visit

http://sd-www.jhuapl.edu/TIMED.

Answer key for worksheet:

1) P = (.15)(Area of Panel)(Incidence of the Sun). Any variables may be used.

2) 15,660 W	3) 5 m	4) 6 m^2
5) 25%	6) 93.3 m^2	7) 1.72 m^2

Solar Panel – Word Problems

1. The power from the solar cells is equal to only 15% efficiency of the power of incidence from the Sun times the area of solar panels that are affected. Write the general formula.

2. If the dimensions of the solar panel are 8 m by 9 m and the power from the Sun is 1450 W / m^2, what is the power output from the solar panel?

3. If the power output from the solar panel is 4350 W, the power from the Sun is 1450 W / m^2, and the panel width is 4 m, what length does the solar panel need to be?

4. If the power of the Sun is 1450 W / m^2 and the power output of the solar panel is 1305 W, what does the area of the solar panel need to be?

5. What is the percent of efficiency of the solar panels if the area is 56 m^2, the power of the Sun is 1450 W / m^2, and the output power is 20,300 W? *Remember, not all solar cells have the same efficiency.*

6. Using the same power output and power of the Sun from the previous problem, calculate what area is needed with only a 15% efficiency?

7. If the output power was only 500 W, the Sun power was 1450 W / m^2, and the efficiency was 20%, what would the area of the solar panels have to be?

Lesson 3: TIDI – Doppler Shift

Links to Outcomes:

- **Problem Solving—**Demonstrate the ability to solve problems from within and outside of mathematics with applications to real-world situations.
- **Communications—**Demonstrate the ability to communicate mathematics with its unique language and symbolism.
- **Connections—**Demonstrate the ability to connect algebra with real-world applications.
- **Technology—**Demonstrate the ability to use technology where appropriate.
- **Algebra—**Demonstrate the ability to perform algebraic concepts by solving for unknowns.

Overview: This lesson is about the TIDI (TIMED Doppler Interferometer) instrument and its use of Doppler shift to measure solar wind speed. Students will be able to manipulate general equations to solve for unknowns as well as make calculations based on given data.

Grade/Level: Grades 8–12; Regular and Honors Algebra

Duration/Length: 1–2 days depending upon student ability and comprehension level.

Prerequisite Knowledge:

- Algebraic terminology
- Solving multistep equations for one variable
- Scientific notation

Objectives:

- Solve literal equations.
- Use formulas to solve real-world applications.
- Understand Doppler shift by using mathematics.

Materials/Resources/Printed Materials:

- Background information on TIMED and the TIDI instrument
- The printed material in this lesson – one for each student. Also make overhead
- The equation explanation and answer key attached to this lesson.

Development/Procedures: This lesson may be used two different ways, as a lead-in or follow-up to a lesson on solving literal equations.Discuss the mission of TIMED and the TIDI instrument. The worksheet uses the mathematical equation used for Doppler shift. If this lesson is used as a lead-in, you might want to demonstrate how to solve for the different variables. The students should then use the most efficient equation to complete each part of the given chart. If this lesson is used as a follow-up, you might want to do one demonstration for solving one of the unknowns. The students should be able to finish the worksheet on their own or with a partner. Go over the answers with students.

Evaluation:

- Circulate during the activity
- Ask students to explain their answers
- Collect the paper for a grade
- Give a more typical evaluation

Extension/Follow-Up: Work with the science teacher on a unit on Doppler shift or the different ways Doppler shift is used. The activity book by Texas Instruments has a few labs using the Computer Based Lab (CBL) and TI –81/82/83 with the motion detector. The motion detector labs can be used like radar detectors with students.

Background Information on TIMED and the TIDI Instrument

TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is the one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. We study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes.

The TIDI instrument is one of four instruments on the TIMED satellite. TIDI stands for TIMED Doppler Interferometer. TIDI is made up of four telescopes on top of the satellite to measure high-altitude winds by using Doppler shift. The high-altitude winds will be measured from 60 to 180 km above the Earth. The Doppler shift is a measurement of the wavelengths or frequency of either sound or light either emitted or reflected by a moving object. Some examples are motion detectors for alarm systems in homes, Doppler radar used to show weather patterns, and radar guns used by the police to detect how fast an individual is driving. The most useful tool of mathematics to express the velocity of wind is vectors. I found that most students do not encounter this concept until college, so the equation to measure the Doppler shift is in this lesson. The TIDI instrument will use vectors to determine the solar wind velocity. TIDI measurements will give us important information on gravity waves, noctilucent clouds, and ion drifts. For more information on the TIMED Mission and the instrument TIDI, please visit http://sd-www.jhuapl.edu/TIMED.

Explanation of Worksheet and Answer Key

The Doppler shift equation can be found in a physics textbook. The original equation uses Greek letters, which can confuse beginning algebra students. I wrote the equation with more user-friendly variables. Also you will note that the equation has a plus or minus put together. The plus shows the object is moving away from you and the minus shows the object is moving towards you. This is due to the lengths of the wavelengths. Mathematicians combined both equations into one just like the Quadratic Equation. On the worksheet, however, I only put the plus sign. I also would have students do the same problems, but with the minus.

Equation:

$$y = x\left[1 \pm \frac{v}{c}\right]$$

Let y = the apparent wavelength

x = the wavelength at rest

v = velocity of the moving source

c = velocity of light (s could be used instead for the velocity of sound)

Answers:

1) $v = \frac{c}{x}(y - x)$ or $v = \frac{cy - 1}{x}$

2) $c = \frac{xv}{y - x}$

3) $x = \frac{y}{1 + \frac{v}{c}}$ or $x = \frac{yc}{c + v}$

y	x	v	c	Equation No.
700.047	700 nm	20 m/s	≈ 300,000 km/s	# 2
650.325	650 nm	150 m/s	≈ 300,000 km/s	Regular equa.
832.832	832 nm	300 m/s	≈ 300,000 km/s	# 3
900.75	900 nm	250 m/s	≈ 300,000 km/s	# 1

TIDI – Doppler Shift Worksheet

Name ___________________________________

Date ___________________________________

Given the equation for Doppler shift to be: $y = x\left[1+\frac{v}{c}\right]$

1) Solve for *v*.

2) Solve for *c*.

3) Solve for *x*.

Complete the chart using one of the above equations. The last column is for you to place the number of the equation you used to solve for the missing piece. The value you find for the variable *c* will be used for the other three equations because it is a constant.

y	*x*	*v*	*c*	Equation No.
700.047	700 nm	20 m/s		
	650 nm	150 m/s		
832.832		300 m/s		
900.75	250 nm			

Unit III. GEOMETRY

Lesson 1. GUVI Geometry

Links to Outcomes:

- **Problem Solving—**Demonstrate the ability to solve problems from within and outside of mathematics with applications to real-life situations.
- **Communication—**Demonstrate the ability to communicate with the unique language and symbolism of mathematics.
- **Reasoning—**Demonstrate the ability to reason logically and to make and test conjecture.
- **Connections—**Demonstrate the ability to make connections among several mathematical properties with respect to the mathematical discipline and other disciplines.
- **Cooperation—**Demonstrate the ability to solve problems in a cooperative setting.
- **Technology—**Demonstrate the ability to use technology where appropriate.
- **Algebra and Geometry—**Demonstrate the ability to apply algebraic and geometric concepts in the process of solving problems in classroom settings as well as in real-life situations.

Overview: This lesson involves classroom and real-world problem applications of algebraic and geometric properties associated with right triangles and trigonometric ratios. The lesson is a good follow-up of the concepts mentioned. The lesson revolves around the GUVI (Global Ultraviolet Imager) instrument for the TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics) satellite.

Grade/Level: Grades 9–12; Regular or Honors Geometry

Duration/Length: 2–3 days depending upon student ability and comprehension level.

Prerequisite Knowledge:

- Understanding of terminology
- Pythagorean Theorem
- Sine, cosine, and tangent
- Ability to follow detailed instructions

Objectives:

- Do a simple experiment to simulate GUVI.
- Calculate angle of incidence (angle of reflection)
- Calculate length of the beam of light
- Using the above two objectives, apply the concept to measuring the width of layers of material in the mesosphere.

Materials/Resources/Printed Materials:

- Background Information provided on GUVI
- Laser Pointer—The number depends if you want to do this in small groups or to do it as a demonstration in front of the class.
- A stand to hold the light—A ring stand from your science department will work.

- Student worksheet—Overhead of this as needed.
- Mirror—The number depends if you want to do this in small groups or as a demonstration in front of the class.
- Piece of white paper or board to bounce light onto.
- Calculator as needed.

Development/Procedures: Discuss the relationship between math and science; how scientific experiments can be backed by mathematical theories. Discuss the mission of TIMED and the GUVI instrument's role in the over all mission.

Set up the experiment with the guidelines provided on the worksheet entitled Experimental Set Up. The number of copies needed depend upon whether you do this in groups or as a demonstration.

Explain each piece of equipment you are using and its relationship to GUVI. The mirror represents the mirror in GUVI, which allows the instrument more range of vision. The laser pointer represents the sensors. The paper represents the elements that are being detected.

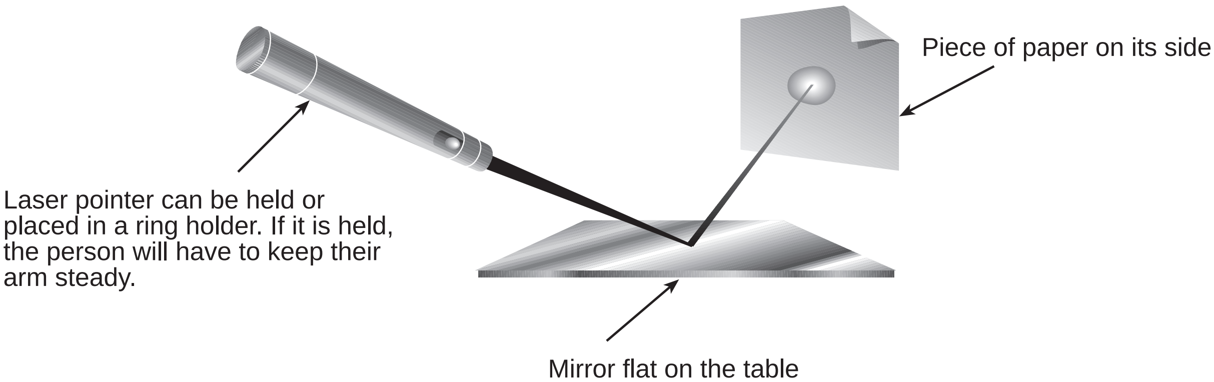
Students will have a worksheet that walks them through the process of the experiment. The worksheet also has extra practice for congruent triangles, trigonometric ratios, as well as the Pythagorean Theorem.

Evaluation: If done as a demonstration, allow different students to come forward to ensure all understand the concepts being demonstrated. If done in groups, circulate through the room to check understanding of the concepts. Further evaluation will occur as part of assigned homework from the textbook and typical evaluation procedures used for your class. You may want to encourage the students to research and design a remote sensor on their own.

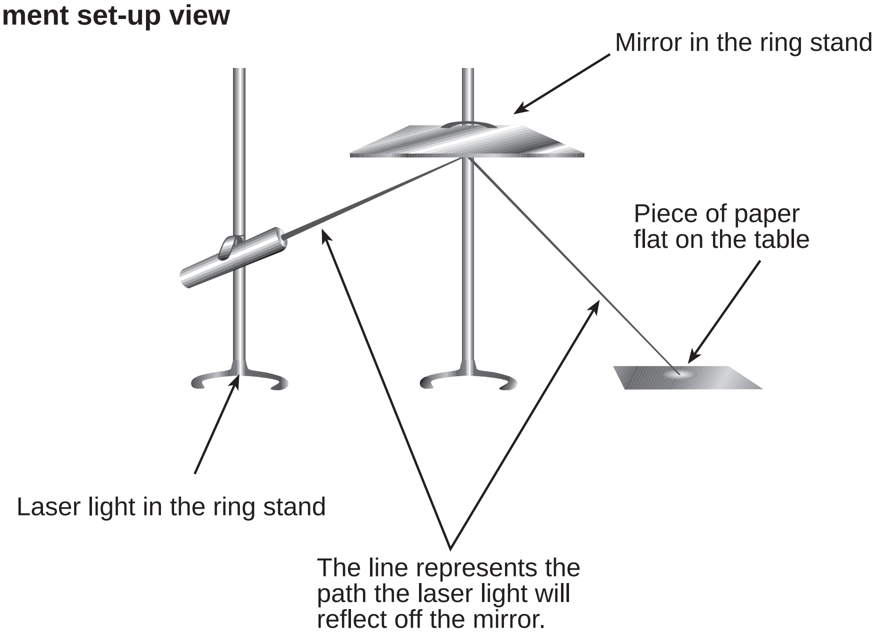
Extension/Follow Up: Work with your science teacher on the subject of electromagnetic spectrum. Since SEE is working with extreme ultraviolet radiation, you and the science teacher may develop another project together.

Experiment Setup

First experiment set-up view



Second experiment set-up view



For the second experiment, the mirror will need to be rotated at different angles, so please get a ring holder that will hold the mirror at all times.

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Background Information on TIMED and the GUVI Instrument

TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is the one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. Teachers and students should study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes such as global warming.

The instrument GUVI is one of the four instruments supporting the TIMED mission. GUVI stands for Global Ultraviolet Imager. GUVI sweeps form horizon-to-horizon scanning for elements in the far ultraviolet spectrum. GUVI's two scientific objectives are to determine the spatial and temporal variations of the densities and temperature in the thermosphere and relative importance of auroral inputs, Joule heating, and solar extreme ultraviolet for the thermal structure of the lower thermosphere. The auroral inputs are the northern lights seen in the night sky over Alaska and other northern areas. The auroral inputs also heat up the very high altitudes. The Joule (unit of energy) heating drives electric currents that heat up the atmosphere.

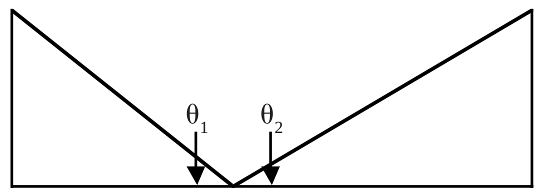
For more information on the TIMED Mission and the GUVI instrument, please visit the home page at http://sd-www.jhuapl.edu/TIMED.

Student Worksheet for GUVI Geometry

Name ________________________________

Date ________________________________

From the first experiment answer the following questions:



1) State the distance from the point where the light beam hits the mirror to the paper.

   ____________________________ = d1

2) State the height of the reflection point on the paper. ____________________ = h1

3) State the distance from the point where the light beam hits the mirror to the laser

   light.________________________ = d2

4) State the height of the laser light from the table to where the beam comes out.

   ____________________________ = h2

5) Label the sketch with the given information.

   a) What do you notice about the drawing? List all information you know.

   ____________________ ____________________

   ____________________ ____________________

   ____________________ ____________________

6) From the information you have, find the two missing angles denoted with the symbols.

   θ_1 = __________ θ_2 = __________

7) What do you notice about the two angles?

The first experiment was to show you generally what the GUVI instrument does. The second experiment will demonstrate how the mirror inside GUVI will work in order to see a larger picture.

Initially, the mirror should be parallel to the table.

8) State the height of the top of the laser light to the mirror. ________________ = h1

9) State the distance from the top of the laser light to the point it hits on the mirror.

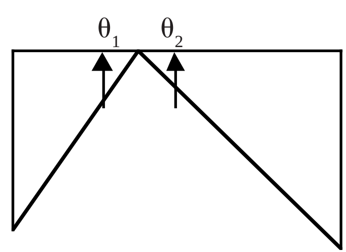
_____________________ = d1

10) State the height from the table to the mirror. ___________________ = h2

11) State the distance from the point on the paper to the point on the mirror.

____________________ = d2

12) Label the drawing (It is not drawn to scale).



13) From the information you have, find the two missing angles denoted with the symbols.

θ_1 = ___________ θ_2 = ____________

14) What do you notice about the two angles?

Angle the mirror in either direction so that the laser light hits the mirror in a different spot and repeat the above steps.

15) State the height of the top of the laser light to the mirror. _________________= h1

16) State the distance from the top of the laser light to the point it hits on the mirror.

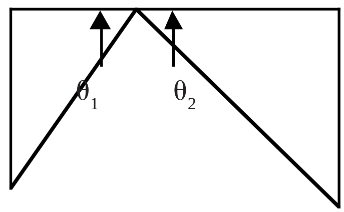
________________________ = d1

17) State the height of the table to the mirror where the point hits it. ____________=h2

18) State the distance from the point on the paper to the point on the mirror.

________________________ = d2

19) Label the drawing (It is not drawn to scale).



20) From the information you have, find the two missing angles denoted with the symbols.
θ_1 = ______________ θ_2 = _______________

21) What do you notice about the two angles?

By now you have noticed that the angle of incidence is equal to the angle of reflection. This is how many instruments work. In order to increase the visibility possible from the instrument up in space, a mirror is used rather than a lens because the mirror provides more range of motion. Many telescopes work according to this principle.

Use the diagram from No. 5 to answer questions 22 and 23.

22) Find the hypotenuse lengths for each triangle.

23) Find the missing angle of each triangle using trigonometry.

Use the diagram from No. 12 for questions 24 and 25.

24) Find the hypotenuse lengths for each triangle.

25) Find the missing angle of each triangle using trigonometry.

Use the diagram from No. 18 for questions 26 and 27.

26) Find the hypotenuse lengths for each triangle.

27) Find the missing angle of each triangle using trigonometry.

Sample Answers for Student Worksheet on GUVI Geometry

Experiment 1

1 – 4. The lengths will vary.

5. Some possible answers are:
Similar triangles
Right triangles
Could use Pythagorean Theorem to find the hypotenuse
Could find the missing angle using trigonometry
Could find the third missing angle by adding the two you know and subtracting from 180

Students might give even more reasonable answers.

6. The measures of the two angles should be about, if not exactly, the same.

7. Students should notice that the two angles are about the same measurement.

Experiment 2

8–12. The lengths will vary.

13. The two angles should be about if not exactly the same measurement.

14. Students should notice that the two angles are about the same measurement.

15–18. You are repeating experiment 2 with the mirror slightly tilted, the lengths will vary.

20–21. Are repeats of numbers 6, 7, 13, and 14.

22–27. The problems are a follow-up to the Pythagorean Theorem and work with trigonometry.

Lesson 2: Orbital Geometry

Links to Outcomes:

- **Problem Solving—**Demonstrate the ability to solve problems from within and outside of mathematics with application to real-life situations.
- **Communication—**Engage in discussions to interpret the given information.
- **Reasoning—**Demonstrate the ability to reason mathematically. Students will make conjectures based on given information and graphs.
- **Connections—**Demonstrate ability to connect geometry with real-world applications.
- **Technology—**Demonstrate the ability to use technology where appropriate.
- **Algebra and Geometry—**Demonstrate the ability to apply algebraic and geometric concepts to solve problems in classroom settings as well as in real-life situations.

Overview: This lesson is more a teacher tool to help bring multiple concepts of geometry together in visuals for students to make conjectures and explore real-world applications. By looking at satellite orbits, students will discover geometric principles.

Grade/Level: Grades 9–12; Regular or Honors Geometry

Duration/Length: 1 – 2 days as either warm-ups or lead-ins to the daily lessons, or follow ups

Prerequisite Knowledge:
- Terminology
- Pythagorean Theorem
- Sine, cosine, and tangent

Objectives:
- Find missing angle measurements using trigonometry.
- Find missing length of segments using trigonometry and the Pythagorean Theorem.
- Understand how geometry is used to locate a satellite.

Materials/Resources/Printed Materials:
- The printed material in this lesson needs to be made into overheads.
- The printed material that goes along with each overhead to help the teacher with explanations or sample problems for each picture.
- Background information on the TIMED satellite; the importance of orbital analysis.

Development/Procedures:
Warm-ups. The diagrams may be used in two different ways: 1) students can write all of the properties they know, or 2) use the drawing to locate a missing angle or length of a segment. Then, discuss background information on TIMED and the importance of orbital geometry. *Lead-in for daily lesson*. The diagrams may be used to discuss the use of the Pythagorean Theorem, trigonometry, finding arc lengths, and inscribed angles. Discuss the background information on TIMED and the importance of orbital geometry. *Follow-ups*. Change the altitude of the satellite for a different orbit and have students do the problems again.

Evaluation: The teacher has many options:
- Circulate during the activity.
- Ask several students to explain their answers.
- Collect the paper for a grade.
- Give a more typical evaluation.

Extension/Follow Up: An orbital specialist could talk about other geometric properties.

Background Information on TIMED and Orbital Geometry

TIMED stands for Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics. The TIMED satellite is the first science mission in the Solar Connections Program to study the Earth's upper atmosphere. The satellite is to be launched in May 2000. This region of our atmosphere is the one which we know and understand the least. The TIMED satellite will be composed of four different instruments that will gather a variety of data—from the speed of solar winds to the density of the different layers of the upper atmosphere. Why do we need to send a satellite to study this region? There are many reasons and potential benefits of studying the Earth's upper region. Because of our increased satellite technology and communications, we need to understand atmospheric variables to increase satellite tracking, spacecraft lifetime, and re-entry piloted vehicles such as the space shuttle. Teachers and students should study the atmosphere to examine how the Earth's upper atmosphere is affecting global changes such as global warming.

Orbital geometry is a tool to help visualize where the satellite will be in relation to the Earth at any given time during an orbit. It also helps introduce the students to trigonometry and pre-calculus concepts. There are many classifications of altitudes of orbits. The main ones are lower Earth orbit (LEO), about 400 – 1000 km; medium Earth orbit (MEO), about 10,000 km; and geostationary orbit (GEO) about 22,300 miles. The two types of orbits are polar orbits, which circle the Earth from pole- to- pole, and equatorial orbits, which circle the Earth around the equator. The Earth science and communication satellites use these two types of orbits, but deep space exploration orbits are different. Those satellites are either traveling to or orbiting another body in space.

For more information on the TIMED mission, please visit the home page at

http://sd-www.jhuapl.edu/TIMED.

Diagram 1: Information and Activities

- The radius of the Earth is 6400 km.
- The distance from the surface of the Earth to the satellite is 635 km.
- The hypotenuse is 6400 km + 635 km.
- The radius and the tangents form 90° angles.
- Find the tangent lengths. When one length is known, then the students know the other is the same length, thanks to a theorem.
- Find the other two missing angles in the triangle using trigonometry.
- If they have the measures of two angles, they can add them and subtract from 180.
- Find the circumference of the Earth.
- Find the area of the Earth.
- Find central angles.
- Find arc lengths.
- Change the orbit length and do the problems again
  - LEO: range from 400 – 1000 km
  - MEO: around 10,000 km
  - GEO orbit: 22,300 miles

Questions about the satellite:

1) If a person is standing on the upper horizon looking out towards the satellite, how far is the person from the satellite?

2) If the satellite needs to down load information to a person on the lower horizon, what is the angle of depression the satellite will need to use to send the information?

Diagram 2: Information and Activities

- The radius of the Earth is 6400 km.
- From the surface of the Earth to the satellite is 635 km.
- The hypotenuse is 6400 km + 635 km.
- The radius and the tangents form 90° angles.
- Find the tangent lengths. When students have found one, then they know the other is the same length, thanks to a theorem.
- Find the other two missing angles in the triangle using trigonometry.
- If they know the measure of two angles, they can add them up and subtract from 180.
- Find the circumference of the Earth.
- Find the area of the Earth.
- Change the orbit length and do the problems again.
  - LEO: range from 400 – 1000 km
  - MEO: around 10,000 km
  - GEO orbit: 22,300 miles

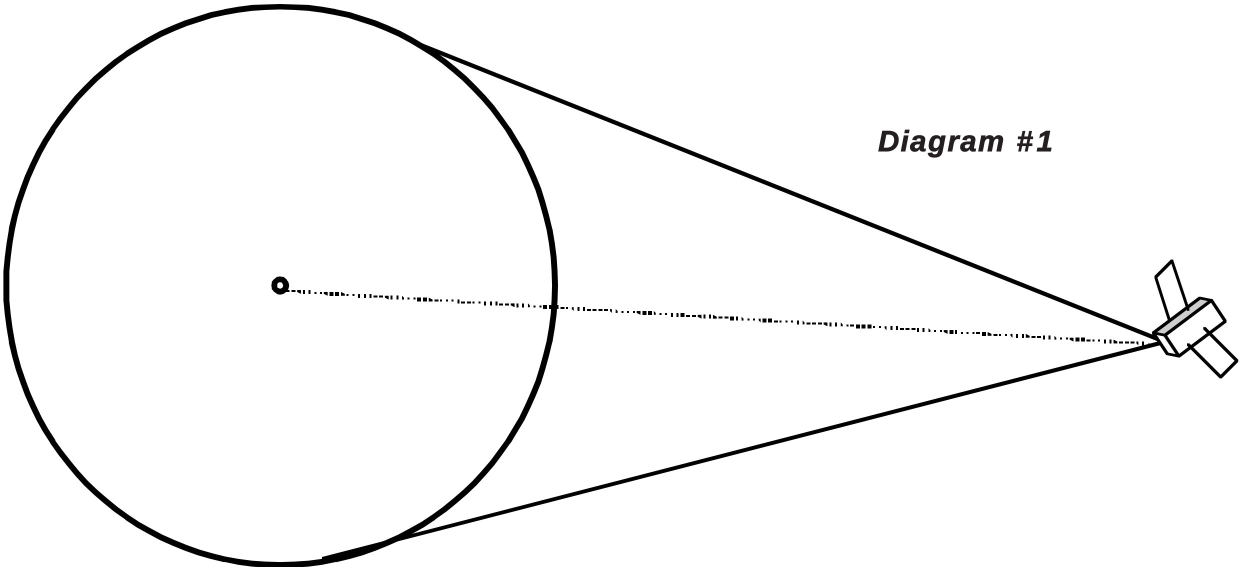


Diagram #1

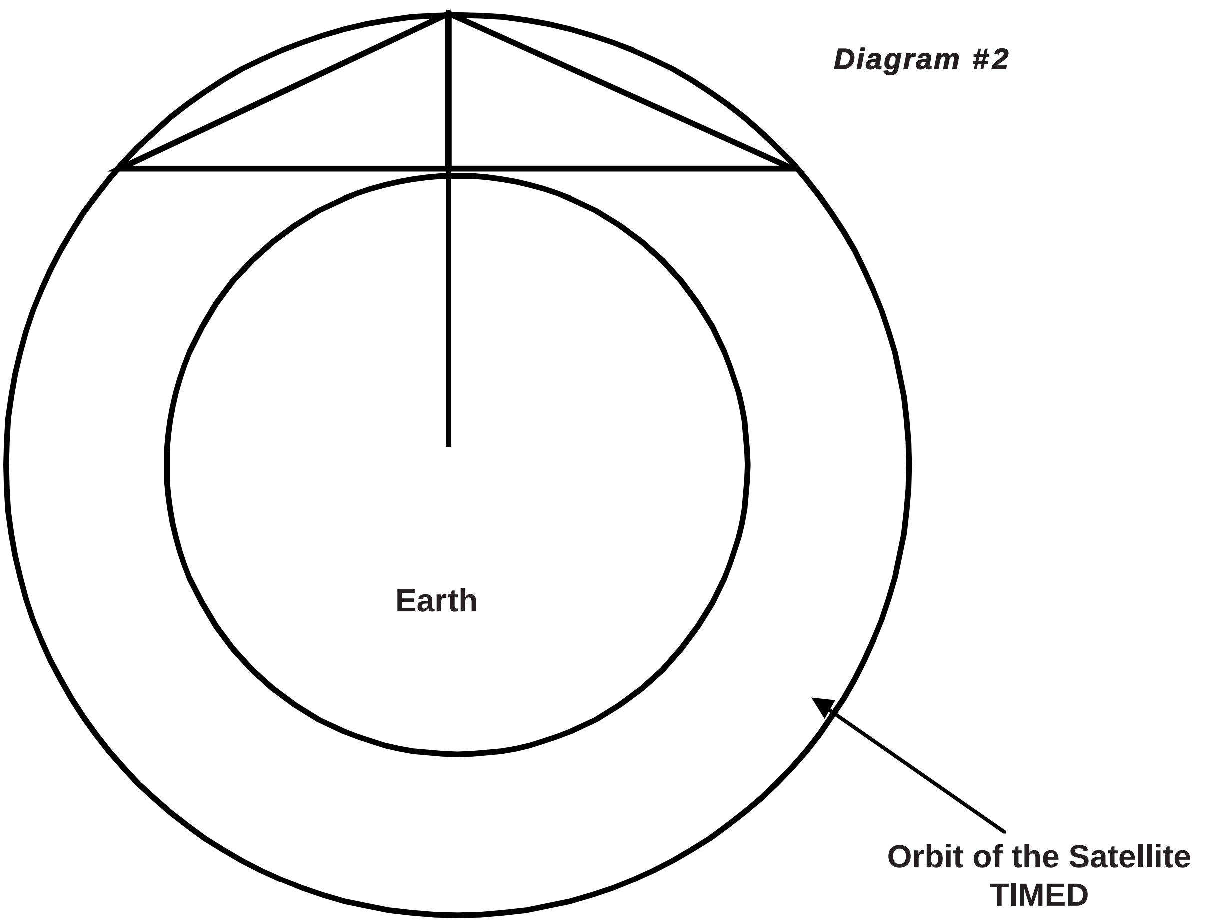


Diagram #2
Earth
Orbit of the Satellite
TIMED